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(54) **REINFORCEMENT OF STRUCTURAL MEMBERS**
VERSTÄRKUNG VON TRÄGERTEILEN
RENFORCEMENT D'ELEMENTS PORTEURS

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Description

[0001] This invention relates to the strengthening of structures and particularly, but not exclusively, proposes an improved strengthening method for providing reinforcement for existing structures or structural members. Suitable structures may comprise any engineering material including, for example, structural and stainless steels, aluminium, cast, iron, concrete, timber, and fibre reinforced plastics, and may be in any form, for example plate-form, tubular or of other hollow cross-section, or in the form of other common engineering sections.

[0002] In many cases, existing structures require reinforcement for strengthening purposes because the standards to which they were designed are no longer considered to be adequate, use of the structure has exceeded that for which it was originally designed, the structure is damaged due to fatigue, corrosion or impact or simply because the structure has reached the end of its expected life.

[0003] Conventionally, such structures are strengthened by the addition of new material of the same type as the existing structure, for example reinforcement of steel or aluminium structures by welding or mechanical fastening techniques, reinforcement of cast iron, timber or fibre-reinforced plastics structures by mechanical fastening techniques, and reinforcement of fibre-reinforced plastics structures by bonding. Where new material of a different type is to be added to a structure, a combination of bonding and mechanical fastening may be used, for example in the attachment of steel plates to a concrete structure. However, these methods have problems associated with either the practicality of their implementation at the worksite or with the structural efficiency of the materials used. Additionally, methods involving welding or mechanical fastening can often result in zones of increased stress which may cause weakening or failure of previously sound areas of the original structure.

[0004] Advanced fibre reinforced polymer composites have properties which make them very well suited to the reinforcement by strengthening of existing structures. Typical fibres include the whole range of carbon fibres, some aramid fibres and some of the high performance glass fibres. The advantages of these materials compared with the common engineering materials from which most structures are manufactured are high specific properties, leading to low weight and compactness, creating a low burden on existing structures and providing easy handling. Additionally, the ability to use adhesive bonding to attach the reinforcing materials reduces stress concentrations in the original structure and the freedom from maintenance of the reinforcing materials reduces through life costs. Advanced fibre reinforced polymer composites are therefore considered to be improved reinforcement materials.

[0005] Advanced fibre reinforced polymer composites are usually manufactured in highly controlled workshop environments sometimes called "clean rooms". Most manufacturing techniques for advanced fibre reinforced polymer composites are based on working in such environments.

[0006] EP-A-0378232 describes one use of advanced fibre reinforced polymer composites to reinforce existing concrete structures. Because the method described results in a composite material having a low fibre volume fraction (and hence comparatively low stiffness and strength) and a low strength bondline, the method is limited in its application to concrete. The materials used in this process are a combination of a pre-preg, and a general purpose room temperature-setting epoxy adhesive.

[0007] GB-A-1490102 describes a method for stabilizing artificial or natural structures which are developing cracks or other voids, thereby lowering the strength thereof and jeopardising the structure should the cracks or voids propagate further. The method involves introducing a liquid or semi-liquid hardenable material into the cracks or voids and to an exposed surface of the structure through a flexible porous sheet of a reinforcing material, by evacuating the cracks or voids and the porous sheet and introducing the hardenable material until all the evacuated voids have been filled, and causing or allowing the hardenable material to set. The flexible porous sheet is preferably a mesh or net, preferably a flexible glass mat.

[0008] US-A-5218810 describes a method for reinforcement of concrete columns to render them resistant to asymmetric loading such as experienced during earthquakes. The method involves wrapping the outer surface of the column with a fabric layer and a resin matrix; the fabric may comprise upper and lower layers stitch-bonded together.

[0009] According to one aspect of the present invention, a method for the strengthening of a substrate structural member comprises the steps of applying, to a surface of the substrate, layers comprising reinforcement material in the form of dry fibres having a high aspect ratio and directionally arranged according to the structural loading requirement of the substrate structural member, applying a reduced pressure to the material layers, introducing a curable resin to the layers such that the resin is drawn therethrough until the interstices therein are substantially filled with resin, and curing the resin.

[0010] The substrate may optionally have a primer or sealer layer initially applied thereto.

[0011] The reinforcement materials preferably include materials having different fibre construction density and permeability, in order to influence the resin distribution properties of the system. The layers may have fibres arranged in two or more directions in order to influence the strength and stiffness properties. Generally, the layers include a layer of a first material having a relatively low fibre construction density and high permeability as a resin distribution layer adjacent the substrate, with one or more further such layers elsewhere in the laminated

system and intermediate layers of a second material having a higher fibre construction density as structural reinforcement layers. The fibres of the structural reinforcement layers have a high aspect ratio (length:width) and are arranged in directions to suit the structural loading requirements. The resin distribution layers generally have a more open disposition of fibres such that resin pathways therein permit resin flow in directions which are both substantially parallel to the principal axes of the longitudinally-disposed fibres of the reinforcement layers and substantially perpendicular to said principal axes. The construction of some of the layers of fabric may be designed to provide different levels of permeability in different directions to control resin flow. In particular, some layers with very low permeability may be included at the interface to the existing structure to promote good bonding to the existing structure, and more such layers at various intervals throughout reinforcements with many layers in order to promote even resin flow throughout. The high permeability layers may be either structural or non structural.

[0012] The final layer may be a removable sealing material designed on removal to allow further applications of reinforcement material or painting without the need for surface preparation.

[0013] Preferably, the dry fibre reinforcement layers comprise from two to sixty layers of fibre-containing material. The fibre volume density may be as high as 50-60% of the cured laminated system. The bond strength of the resin is typically between 15-30 MPa in tensile shear and between 15-35 MPa in pure tension. The material of the resin distribution layers may *per se* contribute structural strength to the resulting reinforcement or may have no, or only limited, intrinsic structural strength in relation to the strength of the structural materials.

[0014] The material of the structural reinforcement layers, which is preferably a woven fabric material, may be selected from one or more of carbon fibres, glass or other vitreous fibre, thermoplastic fibre, aramid fibre, polyethylene and polyester fibres and ceramic fibre. The material of the resin distribution layers may also be formed from such materials if they are intended to provide structural strength. The fibres in both types of material are arranged, preferably substantially within the plane of the layer, in different directions, preferably between 2 and 4 directions, according to the applied load conditions and the fibres in the resin distribution layers are arranged to control flow of the resin. For example a biaxial weave pattern in the material would provide resin pathways in predominantly mutually orthogonal directions. If the resin distribution layers do not *per se* contribute structural strength, they may comprise non-woven fibrous material such as cotton. Where woven fabric materials are used, the fibre construction density is the weave density.

[0015] Advantageously, the method of the invention can be carried out *in situ* thus avoiding the need for so-called clean room environments. The fibre reinforcements may, however, be assembled as a pre-form, which constitutes a further aspect of the invention, containing a plurality of layers of resin-permeable dry fibres having a high aspect ratio, the layers being loosely stitched together and including resin distribution layers having a relatively low fibre construction density and high permeability and strengthening layers having a relatively high fibre construction density and low permeability. The loose stitches allow the pre-form to be shaped to complex curvatures and provide through-thickness strength to the resulting reinforcement.

[0016] Preferably, the pre-form is made in a workshop and then despatched to the work site where the existing structure to which the reinforcement is to be applied is prepared by removing all loose material and surface coatings. Optionally, a primer may be applied to the structure to seal the surface, enhance bonding to the surface or provide electrical insulation between a carbon fibre reinforcing material and the existing structure.

[0017] In order to draw the resin through the reinforcement layers under the influence of reduced pressure, the reduced pressure is generally applied at one end of the layers, in relation to the principal axes of the fibres, and the resin is introduced at the other end, whereby resin flows preferentially through the resin distribution layers, both in substantially longitudinal and substantially perpendicular (vertical) directions relative to the said principal axes, and thence to the reinforcement layers, until the fibres are wetted out, and the interstices are substantially filled or impregnated with resin. The layers are initially covered in use with a flexible, fluid-impermeable sheet member in releasable fluid-tight engagement with the substrate surface, surrounding the layers. A suction duct or manifold in communication with a vacuum pump is disposed under the sheet member at or adjacent one end of the layers,and a resin supply means disposed at or adjacent the other end. Thus, on application of reduced pressure, the sheet member will be drawn by suction into intimate and sealing engagement with at least the upper layer, thus consolidating the reinforcing fabric layers and forcing them into close contact with the substrate surface, and resin will be drawn initially through the resin distribution layers and thence to and through the structural reinforcement layer or layers. Resin continues to be drawn through the layers until the fibre materials are substantially fully wetted out and the interstices are substantially filled with resin; the resin is either allowed to cure as it continues to be drawn through, until the establishment of a gel structure prevents further flow, or is cured after the supply of resin is isolated, still under reduced pressure. The method of curing and the nature of the curing reaction depends on the type of resin, which itself is not critical to the performance of the invention provided that in the liquid state it is sufficiently low in viscosity to penetrate the layers and that in the cured state it has the requisite mechanical properties, resistance to corrosion or aggressive en-

vironments generally, and so on. Thus, the resin may be selected from thermosetting polyesters, epoxy resins, phenolics and vinyl esters among others, and the curing reaction may be addition or condensation polymerisation initiated by a catalyst, free radicals, heat or moisture. Processing at low temperatures may be improved by the addition of air release and wetting agents to the resin before use and by degassing the resin before use.

[0018] If the reinforcement is carried out underwater, the reduced pressure may assist in drying the wet fabric layers before introduction of resin.

[0019] Preferably, in the reinforcement layers, the interstices of the final or uppermost resin distribution layer are blocked at the downstream end region, adjacent the suction duct or manifold, to prevent a direct low-resistance flowpath from occurring between the resin supply means and the suction duct. Where relatively thick laminate layers are required, it is desirable for the final or uppermost layer or layers to be constituted by a relatively highly porous material which may extend around the edges of the lower laminated layers to provide a resin supply distribution and equilibration zone between the resin supply means and the reinforcement layers, to ensure that even those layers the upstream ends of which are not in the direct resin flowpath receive an adequate supply of resin.

[0020] Optionally, a further layer comprising a removable peel or tear ply may be provided over the uppermost resin distribution layer, where there is a requirement for subsequent bonding to or painting of the finished reinforcement. Additionally or alternatively, a layer of an electrically-conductive fabric may be provided over the uppermost resin distribution layer or the ply, to provide for heating of the layers for the purpose of accelerated curing or in situ postcure; such a heating layer can either be removable or incorporated as a permanent element, should there be a requirement for elevated temperatures during the service life of the reinforced material. An overall caul sheet or plate may be provided immediately below the flexible fluid-impermeable sheet member, to consolidate the laminated system, to promote even distribution of the reduced pressure and, where appropriate, to hold the layers in place on a vertical or overhead surface during cure. Such a caul sheet may be formed from a rigid plastics material or a flexible, resilient material such as rubber, and should be of a thickness sufficient to prevent flow of resin from the resin supply means between the reinforcement layers and the fluid-impermeable sheet member, direct to the suction duct. Optionally, the caul sheet may be profiled to provide channels for resin flow as an alternative to the uppermost, partially blocked resin distribution layer.

[0021] When the resin is fully cured, the resin and fibre materials form a composite reinforcement, the resin acting as a bonding and consolidation agent between the fibre material layers and the substrate. The flexible sheet member, peel or tear ply, caul sheet, optionally the conductive fabric, the resin supply means and the suction duct, together with sealants or any other ancillary items of equipment, may all be removed from the thus-produced composite reinforcement.

[0022] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, of which:

Figure 1 is a cross sectional view of reinforcement layers prepared as a pre-form;

Figure 2 shows the arrangement of materials including the pre-form of Figure 1 for repair of a sheet substrate;

Figure 3 shows an arrangement similar to Figure 2 for repair of the flange of a structural girder; and

Figure 4 shows an arrangement similar to Figure 2 for repair of a tubular section.

[0023] With reference to Figure 1, the pre-form shown generally at 10 consists of layers of high-permeability fabric material 11 and layers of higher-density fabric material 12. The layers 11 act as resin distribution layers and the layers 12 act as structural reinforcement layers. The outer (lower-facing) layer 11 is intended to lie adjacent the substrate to be repaired or strengthened in use. The layers are loosely held together by stitching 13. The resin distribution layers 11 improve resin supply to the substrate and throughout the pre-form, whereas the structural reinforcement layers provide strength to the repair.

[0024] Resin distribution layers 11 are formed from a biaxally woven polyester fibre; the initial or lower layer has a lower weave density than the central layer. The structural fibrous reinforcement layers 12 are formed from carbon fibres having mainly longitudinal fibres such that the flowpaths therein are predominantly longitudinally-oriented, whereas the layers 11 have predominantly transverse fibres such that the flowpaths are oriented to provide resin pathways having components directed perpendicularly to the plane of the layers and to the longitudinal direction.

[0025] Referring to Figure 2, the pre-form 10 is shown in position on one face of a plate substrate 21, optionally covered by a removable tear ply sheet 22. A suction channel 23 is disposed at one end of the pre-form and a resin supply pipe 24 is disposed at the other end, surrounded by a highly permeable resin distribution film layer 25 which extends across the top of the pre-form towards the suction channel 23. A resin block 26 is provided at the end adjacent the suction channel 23. A caul plate 27 is optionally disposed over the resin distribution layer 25 and is optionally overlaid with a conductive fabric layer 28. An impervious sheet 29 is placed over the entire assembly and is peripherally sealed to the substrate by use of double-sided adhesive tape or a mastic sealing compound 30. Connections to the conductive

fabric and connections to a vacuum pump and resin reservoir (not shown) for the suction channel and resin supply pipe respectively are provided through the sheet 29 with suitable sealing.

[0026] In use, a suction is applied through the channel 23 and, when the desired reduced pressure has been achieved, resin is allowed to flow into the resin supply pipe 24. Resin is drawn therefrom and flows firstly through the resin distribution layers 25 and then into the pre-form layers, wetting out the fibres. When the desired quantity of resin has flowed into the system, the resin supply is stopped; alternatively, resin is allowed to continue to flow until gelling takes place. The conductive fabric may now be energised to generate heat for accelerating the curing stage or post-curing of the laminate. The pipes, caul sheet, impervious cover sheet, sealant tape and conductive fabric (unless required for service) may now be removed. The peelable tear ply layer may also be removed, either at this stage or before application of further reinforcement/resin distribution layers or painting.

[0027] For general reinforcement purposes on structural steelwork, typical dimensions of the resulting composite reinforcement are 8m length, 500mm width and 35mm thickness. The reinforcement has excellent substrate adhesion and an excellent strength:weight ratio.

[0028] Figure 3 and 4 show arrangements similar to that of Figure 2 as applied to the flange of a girder 31 (Figure 3) and a tube 41 (Figure 4). Typical dimensions for the strengthening of steel beams on an offshore oil production platform are 7m long by 0.2m wide reinforcing patches, each up to 54 layers thick; and for the repair of girth welds in pipelines using circumferential wraps of the reinforcing material, a patch 0.6m long by the circumference of the pipe, each wrap being up to 10 layers thick, may be used.

Claims

1. A method for the strengthening of a substrate structural member (21), characterised in that the method comprises the steps of applying, to a surface (21) of the substrate, layers (12) comprising reinforcement material in the form of dry fibres having a high aspect ratio and directionally arranged according to the structural loading requirements of the substrate structural member, applying a reduced pressure to the material layers, introducing a curable resin to the layers such that the resin is drawn therethrough until the interstices therein are substantially filled with resin, and curing the resin.

2. A method according to Claim 1, in which the substrate has a layer of primer or sealer initially applied thereto.

3. A method according to Claim 1 or Claim 2, in which the layers comprise materials having different fibre construction density and permeability including a layer (11) of a first material having a relatively low fibre construction density and high permeability adjacent the substrate as a resin distribution layer and one or more further layers (12) having a higher fibre construction density as structural reinforcement layers.

4. A method according to any preceding claim, in which the fibres in the reinforcement materials are arranged in different directions.

5. A method according to Claim 3 or Claim 4, in which the structural reinforcement layers include a further resin distribution layer (11) in an intermediate position.

6. A method according to any of Claims 3 to 5, in which the resin distribution layers (11) have a more open distribution of fibres than the structural reinforcement layers (12), such that resin flows in directions which are both substantially parallel to the principal axes of the longitudinally-disposed fibres and substantually perpendicular thereto.

7. A method according to any preceding claim, in which the resin has a bond strength of between 15 and 30 MPa in tensile shear and of between 15 and 35 MPa in pure tension.

8. A method according to any preceding claim, in which the fibre is selected from one or more of carbon fibre, glass or other vitreous fibre, thermoplastic fibre, aramid fibre, polyethylene and polyester fibres and ceramic fibre.

9. A method according to any of Claims 3 to 8, in which the material of the resin distribution layers is nonwoven and comprises cotton.

10. A method according to any preceding claim, in which the resin is a polyester resin, an epoxy resin, a phenolic resin or a vinyl ester resin.

11. A method according to any preceding claim, in which the resin is cured catalytically, by free-radical initiation, by application of heat or by moisture.

12. A method according to any preceding claim, in which the reduced pressure is applied at one end of the layers, in relation to the direction of orientation of the principal axes of the fibres in the fibre-containing material, and the resin is introduced at the other end.

13. A method according to Claim 12, in which the resin is introduced via a resin distribution layer (25) which

is blocked at the downstream end region.

14. A method according to any preceding claim, including the use of a removable peel or tear ply (22), a layer of an electrically-conductive fabric (28), and/ or an overall caul sheet or plate (27) over the reinforcement layers.

15. A pre-form for use in the strengthening of a substrate structural member, characterised in that the pre-form comprises a plurality of layers of resin-permeable dry fibres having a high aspect ratio, the layers being loosely stitched together and including resin distribution layers (11) having a relatively low fibre construction density and high permeability and strengthening layers (12) having a relatively high fibre construction density and low permeability.

16. A pre-form according to Claim 15, in which the fibres in the reinforcement layers are aligned in from 2 to 4 different directions.

17. A pre-form according to Claim 15 or Claim 16, in which one or more resin distribution layers are provided for disposition in use against the substrate (21), and at one or more intermediate locations through the layers of the pre-form.

18. A pre-form according to any of Claims 15 to 17, including a removable sealing material as a final layer.

Patentansprüche

1. Verfahren zum Verstärken eines Substratbauelements (21), dadurch gekennzeichnet, daß das Verfahren die Schritte aufweist

- Aufbringen von Schichten (12) auf eine Oberfläche (21) des Substrats, die Verstärkungsmaterial in Form von trockenen Faser aufweisen, die einen hohen Schlankheitsgrad haben und entsprechend den strukturellen Lasterfordernissen des Substratbauelements gerichtet angeordnet sind
- Anlegen eines reduzierten Drucks an die Materialschichten,
- Einführen eines härtbaren Harzes in die Schichten derart, daß das Harz hindurchgezogen wird, bis die Zwischenräume darin im wesentlichen mit Harz gefüllt sind, und
- Härten des Harzes.

2. Verfahren nach Anspruch 1, bei welchem das Substrat eine anfänglich auf es aufgebrachte Schicht eines Primers oder Porenschließers hat.

3. Verfahren nach Anspruch 1 oder Anspruch 2, bei welchem die Schichten Materialien mit unterschiedlicher Faseraufbaudichte und Permeabilität aufweisen, zu denen eine Schicht (11) eines ersten Materials mit einer relativ niedrigen Faseraufbaudichte und einer hohen Permeabilität angrenzend an das Substrat als Harzverteilungsschicht und eine oder mehrere weitere Schichten (12) mit einer höheren Faseraufbaudichte als strukturelle Verstärkungsschichten gehören.

4. Verfahren nach einem vorhergehenden Anspruch, bei welchem die Fasern in den Verstärkungsmaterialien in unterschiedlichen Richtungen angeordnet sind.

5. Verfahren nach Anspruch 3 oder Anspruch 4, bei welchem die strukturellen Verstärkungsschichten eine weitere Harzverteilungsschicht (11) in einer Zwischenposition aufweisen.

6. Verfahren nach einem der Ansprüch 3 bis 5, bei welchem die Harzverteilungsschichten (11) eine offenere Faserverteilung als die strukturellen Verstärkungsschichten (12) aufweisen, so daß Harz in Richtungen strömt, die sowohl im wesentlichen parallel zu der Hauptachse der längs angeordneten Fasern und im wesentlichen senkrecht dazu sind.

7. Verfahren nach einem vorhergehenden Anspruch, bei welchem das Harz eine Bindefestigkeit zwischen 15 und 30 MPa in Zugscherung und zwischen 15 und 35 MPa in reinem Zug hat.

8. Verfahren nach einem vorhergehenden Anspruch, bei welchem die Faser aus Kohlestoffaser, Glas- oder einer anderen glasartigen Faser, aus thermoplatischer Faser, aus Aramidfaser, aus Polyethylen- und Polyesterfaser und aus Keramikfaser oder aus mehreren davon ausgewählt wird.

9. Verfahren nach einem der Anspruch 3 bis 8, bei welchem das Material der Harzverteilungsschichten nicht gewebt ist und Baumwolle aufweist.

10. Verfahren nach einem vorhergehenden Anspruch, bei welchem das Harz ein Polyestherharz, ein Epoxyharz, ein Phenolharz oder ein Vinylesterharz ist.

11. Verfahren nach einem vorhergehenden Anspruch, bei welchem das Harz katalytisch, durch radikalischen Start oder durch Aufbringen von Wärme oder Feuchte gehärtet wird.

12. Verfahren nach einem vorhergehenden Anspruch, bei welchem der reduzierte Druck auf ein Ende der Schichten bezüglich der Orientierungsrichtung der Hauptachsen der Fasern in dem faserenthaltenden

Material aufgebracht und das Harz am anderen Ende eingeführt wird.

13. Verfahren nach Anspruch 12, bei welchem das Harz über eine Harzverteilungsschicht (25) eingeführt wird, die am stromabseitigen Endbereich blockiert ist.

14. Verfahren nach einem vorhergehenden Anspruch, welches die Verwendung einer entfernbaren Abschäl- oder Abreißlage (22), einer Schicht eines elektrisch leitenden Gewebes (28) und/oder einer Gesamt-Druckkissenbahn oder -platte (27) über den Verstärkungsschichten einschließt.

15. Vorformling zur Verwendung bei der Verstärkung eines Substratbauelements, dadurch gekennzeichnet, daß der Vorformling eine Vielzahl von Schichten aus harzdurchläßigen trockenen Fasem mit einem hohen Schlankheitsgrad aufweist, wobei die Schichten lose zusammengeheftet sind und Harzverteilungsschichten (11) mit einer relativ niedrigen Faseraufbaudichte und hoher Permeabilität und Verstärkungsschichten (12) mit einer relativ hohen Faseraufbaudichte und einer niedrigen Permeabilität aufweisen.

16. Vorformling nach Anspruch 15, bei welchem die Fasern in den Verstärkungsschichten in zwei bis vier unterschiedliche Richtungen fluchtend ausgerichtet sind.

17. Vorformling nach Anspruch 15 oder Anspruch 16, bei welchem eine oder mehrere Harzverteilungsschichten für eine Anordnung bei der Verwendung an dem Substrat (21) und an einer oder mehreren Zwischenstellen durch die Schichten des Vorformlings vorgesehen sind.

18. Vorformling nach einem der Ansprüche 15 bis 17 mit einem entfembaren Dichtungsmaterial als Abschlußschicht.

Revendications

1. Procédé de renforcement d'un élément de structure de substrat (21),
caractérisé en ce qu'
il comprend les étapes consistant à :

    appliquer à une surface (21) du substrat des couches (12) comprenant un matériau de renforcement se présentant sous la forme de fibres sèches ayant un rapport d'exposition élevé et présentant des directions disposées suivant les exigences de chargement structurelles de l'élément de structure de substrat,
    appliquer une pression réduite aux couches de matériau,
    introduire une résine durcissable dans les couches de façon que la résine soit attirée à travers celles-ci jusqu'à ce que leurs interstices soient complètement remplis de résine, et
    faire durcir la résine.

2. Procédé selon la revendication 1,
dans lequel
le substrat comporte une couche d'apprêt ou d'obturation appliquée initialement sur celui-ci.

3. Procédé selon la revendication 1 ou la revendication 2,
dans lequel
les couches comprennent des matériaux ayant des densités de construction de fibres différentes et des perméabilités différentes, ces couches comprenant une couche (11) d'un premier matériau ayant une densité de construction de fibres relativement faible et une perméabilité élevée au voisinage du substrat, pour former une couche de distribution de résine, et une ou plusieurs autres couches (12) ayant une densité de construction de fibres plus élevée que les couches de renforcement structurel.

4. Procédé selon l'une quelconque des revendications précédentes,
dans lequel
les fibres dans les matériaux de renforcement sont disposées dans différentes directions.

5. Procédé selon la revendication 3 ou la revendication 4,
dans lequel
les couches de renforcement structurel comprennent une autre couche de distribution de résine (11) dans une position intermédiaire.

6. Procédé selon l'une quelconque des revendications 3 à 5,
dans lequel
les couches de distribution de résine (11) ont une distribution de fibres plus ouverte que les couches de renforcement de structure (12), de façon que la résine s'écoule dans des directions qui soient à la fois essentiellement parallèles aux axes principaux des fibres disposées longitudinalement, et essentiellement perpendiculaires à celles-ci.

7. Procédé selon l'une quelconque des revendications précédentes,
dans lequel
la résine a une force de liaison de 15 à 30 MPa en cisaillement de tension, et de 15 à 35 MPa en tension pure.

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel la fibre est choisie parmi l'une ou plusieurs des fibres comprenant la fibre de carbone, la fibre de verre ou autre fibre vitreuse, la fibre thermoplastique, la fibre d'aramide, les fibres de polyéthylène et de polyester, et la fibre de céramique.

9. Procédé selon l'une quelconque des revendications 3 à 8, dans lequel le matériau des couches de distribution de résine est un matériau non tissé et comprenant le coton.

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel la résine est une résine polyester, une résine époxyde, une résine phénolique ou une résine d'ester vinylique.

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel la résine est durcie par des moyens catalytiques, par un déclenchement à radicaux libres, par l'application de chaleur ou par l'humidité.

12. Procédé selon l'une quelconque des revendications précédentes, dans lequel la pression réduite est appliquée à une extrémité des couches, par rapport à la direction d'orientation des axes principaux des fibres dans le matériau contenant les fibres, et la résine est introduite par l'autre extrémité.

13. Procédé selon la revendication 12, dans lequel la résine est introduite par l'intermédiaire d'une couche de distribution de résine (25) qui est bloquée dans la zone d'extrémité aval.

14. Procédé selon l'une quelconque des revendications précédentes, comprenant l'utilisation d'un fil d'épluchage ou d'arrachement amovible (22), une couche d'un tissu électriquement conducteur (28), et/ou une feuille ou plaque d'enveloppe d'ensemble (27) sur les couches de renforcement.

15. Préforme destinée à être utilisée pour le renforcement d'un élément de structure de substrat, caractérisée en ce qu' elle comprend un certain nombre de couches de fibres sèches perméables à la résine et présentant un rapport d'exposition élevé, les couches étant cousues ensemble de façon lâche et comprenant des couches de distribution de résine (11) ayant une densité de construction de fibres relativement faible et une perméabilité élevée, ainsi que des couches de renforcement (12) ayant une densité de construction de fibres relativement élevée et une faible perméabilité.

16. Préforme selon la revendication 15, dans laquelle les fibres des couches de renforcement sont alignées suivant 2 à 4 directions différentes.

17. Préforme selon la revendication 15 ou la revendication 16, dans laquelle une ou plusieurs couches de distribution de résine sont prévues pour être disposées, en cours d'utilisation, contre le substrat (21), et en un ou plusieurs emplacements intermédiaires à travers les couches de la préforme.

18. Préforme selon l'une quelconque des revendications 15 à 17, comprenant un matériau d'étanchéité amovible servant de couche finale.

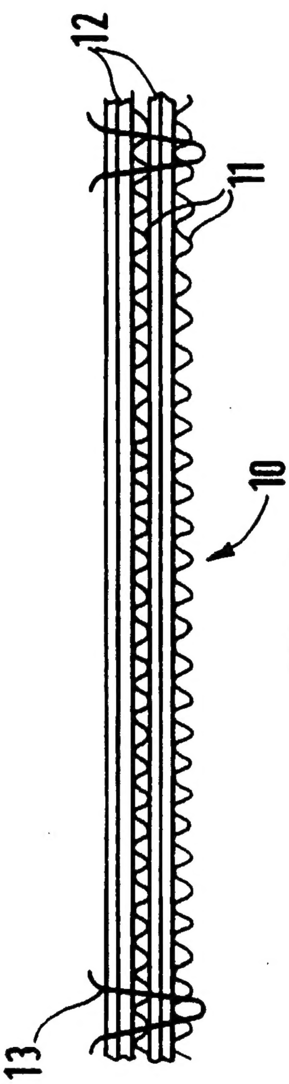

Fig.1.

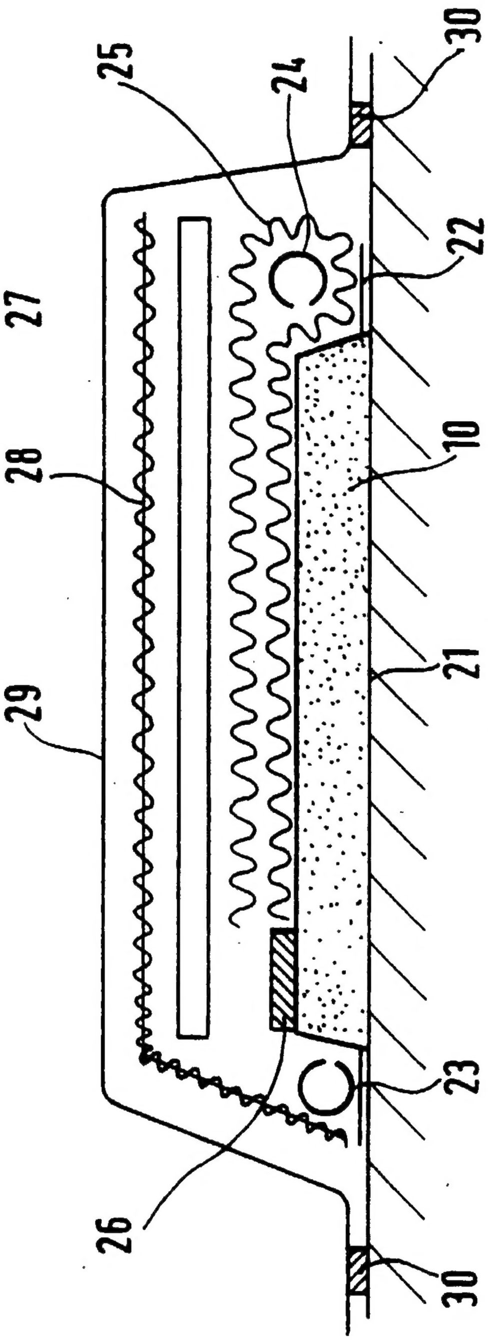

Fig.2.

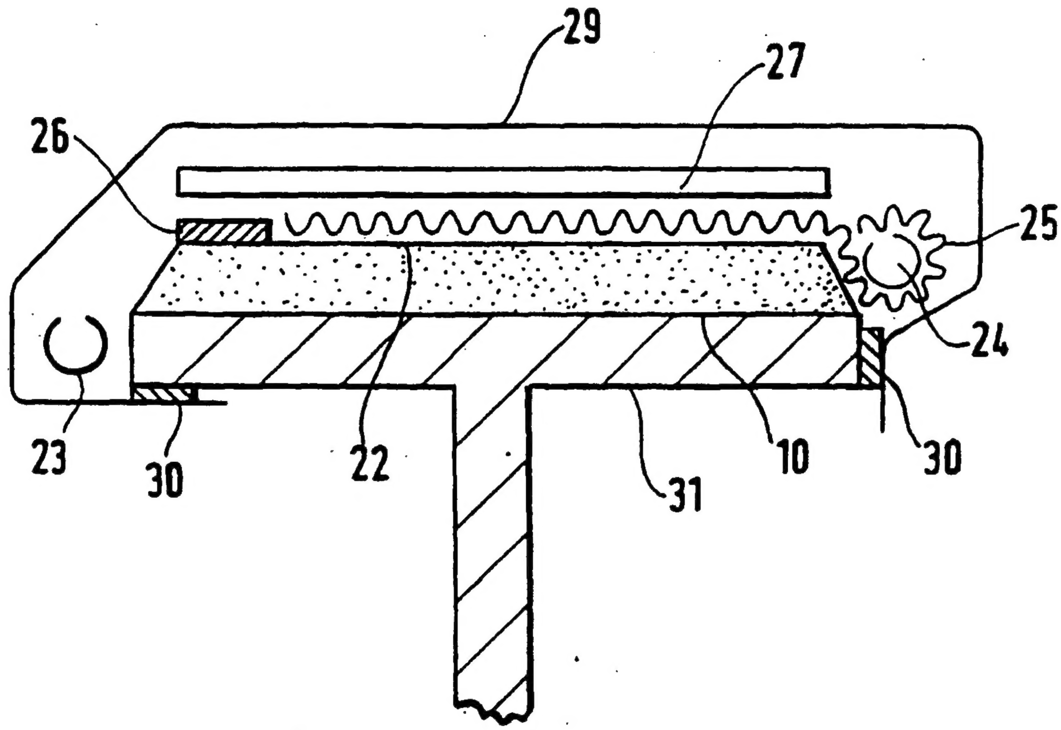

Fig.3.

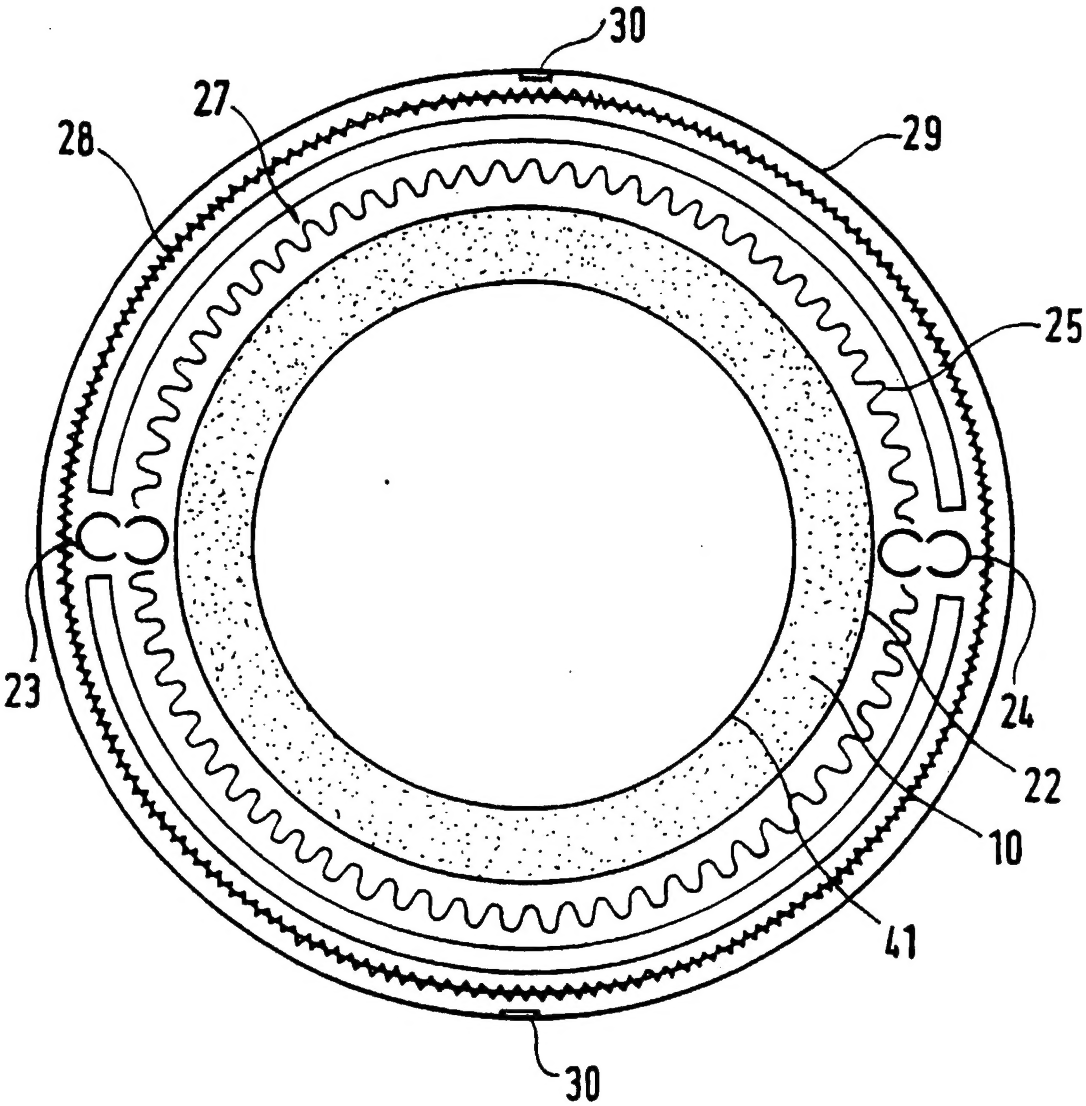

Fig.4.